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Filed : 1 AUGUST 1997

Entitled : POWER ADAPTION IN A MULTI-STATION NETWORK

PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

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Registrateur van Patente
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G.P.-S. 019-0096

SPOOR AND FISHER

FORM P.1

REPUBLIC OF SOUTH AFRICA
PATENTS ACT, 1978

APPLICATION FOR A PATENT

AND ACKNOWLEDGEMENT OF RECEIPT
(Section 30 (1) - Regulation 22)

R 060,00

The granting of a patent is hereby requested by the undermentioned applicant on the basis of the present application filed in duplicate

OFFICIAL APPLICATION NO.			S AND F REFERENCE
21	01	976885	JP/S 1178/jw

FULL NAME(S) OF APPLICANT(S)

71	SALBU RESEARCH AND DEVELOPMENT (PROPRIETARY) LIMITED

ADDRESS(ES) OF APPLICANT(S)

	86/87 FARM DOORNKLOOF, PRETORIA SOUTH, SOUTH AFRICA

TITLE OF INVENTION

54	POWER ADAPTION IN A MULTI-STATION NETWORK

THE APPLICANT CLAIMS PRIORITY AS SET OUT ON THE ACCOMPANYING FORM P.2. THE EARLIEST PRIORITY CLAIMED IS:

COUNTRY: NIL NUMBER: NIL DATE: NIL

THIS APPLICATION IS FOR A PATENT OF ADDITION TO PATENT APPLICATION NO.

21	01	

THIS APPLICATION IS A FRESH APPLICATION IN TERMS OF SECTION 37 AND IS BASED ON APPLICATION NO.

21	01	

THIS APPLICATION IS ACCOMPANIED BY:

- [x] 1. A single copy of a provisional specification of 23 pages.
- [x] 2. Drawings of 9 sheets.
- [ ] 3. Publication particulars and abstract (Form P.8 in duplicate).
- [ ] 4. A copy of Figure .... of the drawings (if any) for the abstract.
- [ ] 5. An assignment of invention.
- [ ] 6. Certified priority document(s).
- [ ] 7. Translation of the priority document(s).
- [ ] 8. An assignment of priority rights.
- [ ] 9. A copy of the Form P.2. and the specification of S.A. Patent Application No.
- [ ] 10. A declaration and power of attorney on Form P.3.
- [ ] 11. Request for ante-dating on Form P.4.
- [ ] 12. Request for classification on Form P.9.
- [x] 13. Form P.2 in duplicate.

74 ADDRESS FOR SERVICE: SPOOR AND FISHER, SANDTON

Dated : 01 AUGUST 1997

C. de V...

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PATENT ATTORNEYS FOR THE APPLICANT(S)

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FORM P.6

REPUBLIC OF SOUTH AFRICA
PATENTS ACT, 1978

PROVISIONAL SPECIFICATION

(Section 30(1) - Regulation 27)

OFFICIAL APPLICATION NO.		
21	01	976885

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FULL NAME(S) OF APPLICANT(S)

71	SALBU RESEARCH AND DEVELOPMENT (PROPRIETARY) LIMITED

FULL NAME(S) OF INVENTOR(S)

72	MARK SIEVERT LARSEN; JAMES DAVID LARSEN

TITLE OF INVENTION

54	POWER ADAPTION IN A MULTI-STATION NETWORK

BACKGROUND OF THE INVENTION

This invention relates to a method of operating a multi-station communication network and to communication apparatus usable to implement the method.

International patent application no. PCT/GB 95/02972 describes a communication network in which individual stations in the network can send messages to other stations by using intermediate stations to relay the message data in an opportunistic manner. In networks of this kind, and in other multi-station networks, it is desirable to control the output power of transmitting stations to a level which is sufficient for successful reception of transmitted data, but which is otherwise as low as possible, to minimise interference with nearby stations or with other users of the radio frequency spectrum.

It is an object of the invention to provide a method of operating a multi-station communication network which addresses the above objective.

SUMMARY OF THE INVENTION

According to the invention there is provided a method of operating a communication network comprising a plurality of stations able to transmit data to and receive data from one another, the method comprising:

monitoring, at each station, the path loss between that station and each other station with which that station communicates;

recording, at each station, path loss data corresponding to the path loss associated with each said other station; and

setting, at each station, a transmission power value based on the recorded path loss data associated with a selected other station when transmitting data to said selected other station, thereby to increase the probability of transmitting data to said selected other station at an optimum power level.

The path loss at a station receiving a data transmission may be calculated by comparing the measured power of the received transmission with data in the transmission indicating the transmission power thereof.

The method preferably includes transmitting path loss data corresponding to the path loss between a first and a second station when transmitting other data between the stations, so that path loss data recorded at the first station is communicated to the second station for use by the second station and vice versa.

A station receiving such path loss data preferably will compare the received path loss data with respective stored path loss data and calculate a path loss correction value from a difference between the received and stored values, the path loss correction value being utilised to adjust the transmission power when transmitting data to the station which transmitted the path loss data.

The path loss correction factor may be calculated by deriving rate of change data from a plurality of path loss correction factor calculations.

Further according to the invention there is provided communication apparatus operable as a station in a network comprising a plurality of stations which can transmit data to and receive data from one another, the communication apparatus comprising:

transmitter means arranged to transmit data to selected stations;

receiver means arranged to receive data transmitted from other stations;

signal strength measuring means for measuring the power of received transmissions;

processor means for recording path loss data corresponding to the path loss associated with other stations; and

control means for adjusting the output power of the transmitter according to the path loss between the apparatus and a destination station.

The processor means is preferably arranged to calculate the path loss by comparing data in received transmissions relating to their transmission power and/or a previously measured path loss with the measurements made by the signal strength measuring means.

The processor means is preferably arranged to extract path loss data from received transmissions, to compare the path loss data with the measured power of received transmissions, and to calculate a path loss correction factor from the difference therebetween, the path loss correction factor being utilised by the control means to adjust the output power of the transmitter.

The processor means may be adapted to derive rate of change data from a plurality of path loss correction factor calculations, thereby to compensate for variations in the path loss between stations.

Preferably, the processor means is arranged to store path loss data for each of a plurality of stations and to set an initial transmission power value when initiating communication with any of said plurality of stations according to the respective stored path loss data.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is schematic diagram of a multi-station communication network, indicating how an originating station can transmit data via a plurality of intermediate stations to a destination station;

Figures 2A to 2E are a simplified flow diagram indicating graphically the operation of the method of the invention; and

Figures 3 to 6 are schematic block diagrams of apparatus according to the invention.

DESCRIPTION OF EMBODIMENTS

The network illustrated schematically in Figure 1 comprises a plurality of stations, each comprising a transceiver able to receive and transmit data from any other station within range. A communication network of this kind is described in PCT patent application no. PCT/GB 95/02972, the contents of which are incorporated herein by reference. The stations of the network maintain contact with one another using the probing methodology described in South African patent application no. 97/5022, the contents of which are also incorporated herein by reference.

Although the method and apparatus of the present invention were designed for use in the above referenced communication network, it should be understood that the application of the present invention is not limited to such a network and can be employed in other networks, including conventional cellular or star networks, or even in a two-way communication situation between first and second stations.

In Figure 1, an originating station A is able to communicate with five "nearby" stations B to F, and is transmitting data to a destination station O via intermediate stations B, I and M.

When any of the stations transmit data to any other station, it is necessary that the transmit power used be sufficient to enable successful reception of the transmitted data at the receiving station. At the same time, to avoid unnecessary energy consumption and interference with other stations in the network, or other communications systems in general, it is desirable to minimise the transmission power utilised.

The problem of setting an optimum transmission power is complicated by variations in the path loss between stations, which may be severe in the case of stations which are moving relative to one another.

The present invention addresses this problem by providing a method and apparatus for continually monitoring the path loss between stations and adjusting the transmission power used when transmitting data, so as to use just enough power to ensure successful reception of the transmitted data, without transmitting at a higher power than is required.

When a station receives a data package from a remote station it measures the power or strength of the received transmission. This is known as the Received Signal Strength Indicator (RSSI) value of the received transmission. In the data packet from the remote station there is included data corresponding to the transmission power used by the remote station. The local station can therefore calculate the path loss between the two stations by subtracting the locally measured RSSI value from the transmission power value in any data packet. Whenever a local station responds to a probe signal from a remote station, it will always indicate the path loss it has calculated in the response data packet. Likewise, the local station knows that any data packets addressed to itself will contain data

corresponding to the path loss measured by the remote station from the most recent probe signal received by that remote station from the local station.

The local station will compare its calculated path loss with the path loss data received from the remote station, and will use the difference in the path loss values to determine a correction factor to use when transmitting data to the remote station, thereby to adapt its output power to an optimum level, or as close to it as possible.

The first time the local station hears from the remote station it will use a correction factor of:

$Path_{Cor}$ = Remote Path Loss - Local Path Loss

Thereafter:

$Path_{Cor}$ = $Path_{Cor}$+(((Remote Path Loss - Local Path Loss)+$Path_{Cor}$)/2)-$Path_{Cor}$)

where the maximum adjustment made to $Path_{Cor}$ in both cases is 5 dB up or down.

$Path_{Cor}$ may only be a maximum of ± 30dB.

The local station adds the correction factor $Path_{Cor}$ to its measured path loss, thus generating a Corrected Path Loss value when determining what power to use when responding to the remote station. However, the Path Loss value it places in the packet header is its measured Path Loss without correction.

If the local station does not get a direct response from the remote station after ten transmissions then it must increase its $Path_{Cor}$ value by 5dB to a maximum of +10dB. The reason for doing this is to avoid going below the noise threshold of the remote station. (The $Path_{Cor}$ value is added to the measured Path Loss. The adjusted Path Loss is then used to determine the required transmission power. A smaller value for $Path_{Cor}$ will correspond to a lower transmission power. Therefore, if the $Path_{Cor}$ value is made too small or even negative then the transmission power may be to low to reach the remote station. It is therefore necessary to increase the $Path_{Cor}$ value in 5dB steps until a response from the remote station is detected).

The local station will also not increase its transmission power more than 10dB above normal. This is to avoid swamping other stations if there is an error with the remote station's receiver. However, if the local station does receive a response then the maximum adjustment may go as high as 30dB above normal.

If the RSSI of the remote station is pegged it will set its Path Loss value in the data packet header as 0 (zero). A station will not make any adjustment to its path loss correction factor if either the remote Path Loss in the header is at zero, or if its local RSSI is pegged.

Having calculated the Path Loss and the correction factor $Path_{Cor}$, the local station can now determine the power required to transmit back to the remote station. The remote station also includes in every packet it sends the background RSSI values for the current, previous, and next modem. The local station will use the Corrected Path Loss and the remote background RSSI value to determine what power to use when responding.

Each station has a minimum Signal to Noise (S/N) ratio level that it will try to maintain for each modem. It is assumed that the required Signal to Noise ratio of all the stations in the network is the same. The local station will set the power level for its transmissions such that the remote station will receive them at the correct S/N ratio. If the local station has additional data to send, or if it can operate at a higher data rate, then the required S/N ratio required may vary.

Example 1

Remote station Tx Power	: 40 dBm
Remote Station Background RSSI	: -120 dBm
Remote Station Path Loss	: 140 dB
Local station Required S/N	: 25 dB
Local station Path Loss	: 130 dB

Path_{Cor} = Remote Path Loss - Local Path Loss (Assume first time)
= 140 - 130
= 10 dB

Corrected Path Loss = Local Path Loss + Path_{Cor}
= 130 + 10
= 140 dB

Local Tx Power = Remote RSSI + Required S/N + Corrected Path Loss
= -120 + 25 + 140

= 45 dBm

From the above example it can be seen that the local station must use a Tx Power of 45 dBm to obtain a remote S/N ratio of 25 dB. If the local station can only set its power in 10 dB steps then it must adjust its power up to the next step, ie. 50 dBm.

A station may have one or more modems. Each modem operates at a different data rate. However, they all operate in the same channel, ie. frequency and/or medium. Therefore when a station changes channels all the modems will be available on the new channel. A channel may however have a minimum and/or maximum data rate associated with it. For example if a station is on a 80 kbps probing channel it may not use data rates lower than 80 kbps. Therefore it may not use the 8 kbps modem on that channel. In the same way the 8 kbps probing channel may have a maximum bandwidth of 80 kbps, therefore not allowing the use of the 800 kbps modem on that channel.

When a station is probing on a probing channel, it will use the data rate associated with the channel. It will always probe on the channel and at the power required to maintain 5 neighbours.
When a local station responds to the probe of a remote station, or if it responds to a data packet of a remote station, it will always try to use the optimum modem for its response.

A station will always try to respond at the highest data rate possible. The highest data rate will be determined by the maximum data rate allowed for the channel and by, the remote S/N ratio on the modem associated with that

data rate.

If a station can use a higher data rate on the channel, it will determine the remote S/N for that data rate. If it can achieve that required S/N ratio it will use the higher data rate. On the other hand, if the conditions are poor and the station can't achieve the required S/N ratio then it will remain at the current data rate. When condition are very poor and the station can't maintain the current data rate, it may even choose to respond at a lower data rate, if the channel allows. It will only use a lower data rate if the S/N ratio of the lower data rate is achieved. If the station cannot use a lower data rate, and if it is on the lowest data rate available then the station will try anyway. However, if there is a lower data rate available, but the station may not use it on the current channel, then the station will not respond to the remote station. This will force the remote station to find a lower data rate channel.

In summary:

- A station will switch to the next modem if the S/N ratio of the next modem meets the required S/N ratio and the maximum modem rate of the channel allows the next modem to be used.

- A station will switch to the previous modem if the S/N ratio of the current modem is below the required S/N ratio and the S/N ratio of the previous modem meets the required S/N ratio and the minimum modem rate of the channel allows the previous modem to be used.

When a station responds to another station it will always try to send as much data as it can. The factors which limit the packet size are: spacing between probes, maximum transmission power, and the allowed transmission duration on a data channel.

In the prototype system, the base packet size is 127 bytes. This is the smallest packet size that will allow data to be reliably transmitted between two stations. (This assumes there is data to send. If a station has no data to send then the packet will always be smaller than 127 bytes.)

A station will use the base packet size under very bad conditions even when it has more data to send. Thus if it is sending to a remote station which has bad background noise, or is very far away, it will only be able to respond at the lowest data rate (8 kbps), and at maximum power.

If a station can achieve a remote S/N ratio better than the base value (i.e. Required S/N for 8 kbps), it may start using larger packets based on the

For a 10x baud rate increase it will multiply the packet size by a factor Z. (Typically Z = 4)

Multiplier for packet size = $Z^{\log(X)}$, where X is Baud 2 / Baud 1.

For a 10dB S/N increase, multiply packet size by Y (Typically Y = 2)

Multiplier for packet size = $Y^{W/10}$, where W is additional S/N available.

The values for Z and Y are fixed for the entire network. Typical values for Z and Y are 4 and 2 respectively.

Example 2

If a station can respond at 80 kbps at the required S/N ratio for 80 kbps, it will then use a maximum packet size of 127 * $4^{\log(80000/8000)}$ = 127 * 4 = 508 bytes. If the station cannot fill the packet, it will still use the power required to achieve the required S/N ratio.

Example 3

If a station can respond at 15 dB above the required S/N ratio for 80 kbps, it will then use a maximum packet size of 127 * $4^{\log(80000/8000)}$ * $2^{15/10}$ = 127 * 4 * 2.83 = 1437 bytes. If the station cannot fill the packet it will drop its transmission power to the level required for the packet size it will actually use. For example, even though it could use a packet size of 1437 bytes, if it only has 600 bytes to send to the other station it will adjust its Tx power to a level between the required S/N and 15dB above the required S/N by using the inverse of the equation $Y^{W/10}$ to determine how much additional power it needs above the required S/N ratio.

It is important to note that even though a station may use a larger packet size based on the available S/N ratio and data rate, the packet size may be limited by the probe interval. For example, if the probe interval on the 8 kbps channel is 300 milliseconds, and the maximum packet size based on the available S/N ratio is 600 bytes (which translates to 600 milliseconds at 8

kbps), it can be seen that a packet size of less than 300 bytes must be used, otherwise other stations may corrupt the packet when they probe.

A number of factors must be taken into account when trying to determine the maximum packet size based on the probing rate. These factors include: Tx on delay (the time for the transmitter power amplifier to settle, and for the remote receiver to settle), modem training delay (length of modem training sequence), turnaround delay (time for processor to switch from Rx to Tx, ie. to process data), and propagation delay (time for signal to travel through medium).

To determine the maximum packet size based on the probing rate the following equation is used:

Max Length (ms) = Probe interval - Tx on delay - modem training delay - turnaround delay - propagation delay

The length in bytes can then be determined by:

Max Length (bytes) = Data Rate / 8 * Max Length (seconds)

<u>Example 4</u>

Probe interval is 300 milliseconds on 8 kbps channel. Tx on delay 2 milliseconds, modem training delay is 2 milliseconds, turnaround delay 3 milliseconds, propagation delay 8 milliseconds (worse case for station 1200 km away).

Max Length (ms) = Probe interval - Tx on delay - modem training delay - turnaround delay propagation delay
= 300 - 2 - 2 - 3 - 8
= 285 ms

Max Length (bytes) = Data Rate / 8 * Max Length (seconds)
= 8000 / 8 * 0.285
= 285 bytes

Figures 3, 4, 5 and 6 show the basic hardware used to implement the invention. These Figures correspond to Figures 8, 9, 10 and 11 of the abovementioned international patent application no. PCT/GB 95/02972.

Based upon its "decision" to transmit, the main processor 149 will decide on a power level data rate and packet duration to use and will send this packet to the serial controller 131 and simultaneously through the peripheral interface 147 switch the transmit/receive switch 103 into transmit mode and switch the transmitter on after a suitable delay. The Zilog chip 131 will send the packet data together with a suitable header and CRC check via the PN sequence encoders in block 128 or 130, depending on the data rate chosen.

The main processor 149 will embed in the data packet, as one of the fields of information, data corresponding to the transmit power it is using, which will be the same transmit power as sent to the power control PIC block 132, which in turn is used to drive the power control circuit 141, which in turn controls the gain control and low pass filter block 143. This block in turn uses feedback from the power amplifier 145 to control the drivers 144 and

142.

The sensing and gain feedback method allows a reasonably accurate power level to be derived based upon the instruction from the power control circuit 141.

Prior to switching the power amplifier on, the transmission frequency is selected by the synthesizer 138, after which the power amplifier 145 is instructed via the driver block 141 and the amplifier is switched on.

If power levels below the minimum power level provided by the power amplifier 145 are required, the switched attenuator block 102 may be switched in, in order to provide up to an additional 40 dB of attenuation. Therefore the processor can instruct the power amplifier to switch in an attenuator combination to provide an output power level ranging from minus 40 dBm to plus 50 dBm. When the amplifier is switched on, the processor obtains information from the low power sensing circuit 101 as to the forward and reverse power, which is sent via the analogue to digital converter 146 and is used by the main processor 149 in order to monitor the level of power being transmitted. This information is then stored in the dynamic RAM 150 to provide information as to forward and reflected power levels actually generated by comparison to the level requested.

The amount of output transmit power will be affected by the efficiency of the transmit power control loop (blocks 145, 144, 142 and 143) and the switched attenuator block 102. In addition, any mismatch in the antenna 100 will also result in variations in reflected and forward power. The relative power actually output for various levels required can be stored by the

processor in the RAM providing a table giving requested against actual power output levels. This can be used to allow the processor to use a more accurate power level field in the information it provides on future transmissions, within messages or probe signals. Since the power level is varied from between minus 40 dBm to plus 50 dBm there are effectively ten different power levels spaced 10 dB apart that may be transmitted. Therefore, the table stored by the processor will have these ten power levels, with the requested power level and actual power level being in this range.

Any other station in the network will then receive this transmission via its antenna 100. The received signal will then pass through the low power sensing circuit 101 and the switched attenuator 102, which initially is set for 0 dB attenuation. It will then pass through the 2 MHz bandpass filter 104, which will remove out of band interference, and then passes into the preamplifier 105, which amplifies the signal before it is mixed down via the mixer 106 to a 10.7 MHz IF signal. This signal is filtered by the bandpass filler 107, and amplified in the IF amplifier 108 and further filtered and amplified in blocks 109, 110, 111 and 112.

The final filtering occurs at blocks 114 and 115, at which stage the signal is measured at block 116 using the narrowband RSSI function, the output of which is used via the main processor to determine the signal strength of the incoming transmission. This then allows the processor, if necessary, to request the power control PIC circuit 132 to switch in additional receiver attenuation up to 40 dB. The switching in of additional attenuation in will only be necessary if the signal exceeds the measurement range of the NE615 of block 116. Otherwise, the attenuator is left at 0 dB attenuation, allowing the full sensitivity of the receiver to be available for receiving small signals.

The incoming transmission is measured in two bandwidths simultaneously, namely 8 kHz and 80 kHz. The 80 kHz bandwidth is measured by tapping off the 10.7 MHz IF signal after the 150 kHz ceramic filter 109 and using a 150 kHz ceramic filter 121 and an NE604 IC 120. This, too, has an RSSI output which is received via the interface by the main processor 149.

The broadband and narrowband RSSI are measured via the analogue to digital converter 146, which then passes the data on to the main processor 149. The main processor has a lookup table, and takes the information from the A to D converter and derives from previously calibrated data a receive signal strength. This data is calibrated in dBm, typically from minus 140 dBm to 0 dBm. This information is typically generated using the output of a calibrated signal generator, injecting this into the input of the receiver, and then dialling up various signal strength levels and instructing the processor via the keyboard 209 as to what power levels are being injected. This information is then stored permanently in static RAM or flash RAM 150.

Therefore, the receiving station can accurately record the power level of any incoming transmission. It then reads the address of the incoming transmission and its embedded transmit power level. By comparing these, for example, a plus 40 dBm transmit power level may be measured in the receiver as minus 90 dBm and this is then used to compute a path loss of 130 dB. Path losses may vary from 0 dB up to a maximum of 190 dB (+50 - (-140) = 190). The minimum path loss that can be measured is dependent on the transmission power of the transmitting station and the maximum signal that can be measured by the receiving station. Since with this design the maximum receiving signal is 0 dBm at the antenna port 100, a 0 dB path loss can be measured, providing the transmit power is less than 0 dBm.

Otherwise, for example, at a transmit power of 50 dBm the minimum path loss that can be measured is 50 dB. This could be improved by adding additional steps in the switched attenuator or through using a different arrangement in the receiver. If the switched attenuator is fully switched in and the output of the A to D convertor indicates that the RSSI is at its highest level, the receiving processor will tag the data associated with the transmission as being "pegged". This means that the path loss is less than is measurable.

The processor on receive will continually measure the background signal and interference, and providing that no transmissions are detected on either modem at either data rate, will monitor and measure the noise and interference in dBm and generate an average which will be stored in the static RAM. When a transmission is detected, the most recent noise measurement is compared to the signal strength to derive a signal to noise ratio. On each transmission, the background noise picked up prior to transmission is advertised inside the transmission message or probe as another field together with the transmitted power. Other stations in the network can pick up and derive from transmission not only the path loss but also the distant station's noise floor just prior to its transmission. The receiving station, since it knows the path loss and has the noise floor of the distant station, will then know at what power to transmit to achieve any desired signal to noise ratio at the distant station.

The required signal to noise ratio is typically based upon the performance of the modem and a figure based upon packet duration and probability of success. This required signal to noise ratio is stored in the database by the processor and is continually updated, based upon the success of transmissions

to various destinations. If a station, for example, picks up a transmission and calculates the path loss to be 100 dB and the distant station to have a declared noise floor of minus 120 dBm, to meet the required signal to noise ratio of for example, 20 dB for 8 kilobits per second, it will then transmit at a power level of minus 20 dBm. This required signal to noise ratio will be different for 80 kilobits per second in that the noise floor would be higher in the wider bandwidth of 150 kHz by comparison to 15kHz and in that the performance of the 80 kilobits per second modem may be different from that of the 8 kilobits per second modem.

Therefore, the receiving station would know that if, for example, the declared noise floor in the wideband is minus 110 dBm and the path loss would still be 100 dB, but the required signal to noise ratio is, for example, 15 dB, it would require a transmission power of plus 5 dBm. The station receiving the transmission will know what power level to use to respond to the originating station.

Monitoring other communicating stations, the receiving station will see the path loss variation and the noise floor declared by various other stations it is monitoring varying as well, and through choosing a moment of minimum path loss and minimum noise floor will transmit at the appropriate power level to achieve the required signal to noise ratio to the station or stations that it is monitoring. In responding to a transmission, the responding station will switch on its transmitter, control the power amplifier via the power control PIC 132 to meet the required power level and then the main processor 149 will embed the fields of its own transmit power, its own receive noise prior to transmission and the path loss that it has just received from the station to which it is responding.

Depending on the signal to noise ratio and the power level required, the main processor will elect to switch in either the 80 kilobit per second or 8 kilobit per second modem and make the transmission. On making this transmission, it will embed its own transmit power level, its own background noise floor measured in both the 150 kHz and 15 kHz bandwidth and the path loss it has just calculated for the transmission to which it is responding. The originating station, on receiving the transmission, will again measure the RSSI in the two bandwidths and via the A to D converter 146, and using the lookup table in the static RAM 150, calculate the received signal strength. By examining the received packet passed from the Zilog synchronous serial chip 131, it will calculate the received path loss using the transmitter power declared and the measured RSSI and compare the path loss value sent to it by the other station.

In comparing these two path losses, since only a short period of time has elapsed between transmission and reception, these two path losses should be quite similar unless the path loss is fluctuating, caused perhaps by a moving vehicle environment. In successive transmissions, the difference between the two path loss values is averaged and stored since this number represents the difference due to measurement error in signal strength or error in the declared power level being transmitted. The averaging process is used to average out, say, the effects of moving vehicles and path loss fluctuation. The main processor will use this averaged number and retain one for every station in the network. It will have a path loss correction factor or delta ranging from a few dB to tens of dB for each station in the network which it will store in RAM. On detecting any station transmitting and measuring the path loss, the correction factor is then used to correct the transmit power level before responding to the station. A typical process is as follows:

Station A measures the incoming path loss from Station B, of say 100 dB. Station A looks at Station B's address which is then compared to a lookup table to determine correction factor or the delta, for example 10 dB plus. This means that the path loss as measured by Station A is on average 10 dB higher than that measured by Station B. Based upon the path loss just measured by Station A and Station B's, noise, the power level required is calculated by Station A to meet the required signal to noise ratio at Station B. The difference allowed between the declared path loss by Station B and the measured path loss by Station A is stored by Station A. If a strong variation is detected, this is in all probability due to fluctuating path loss between transmissions, and therefore, the receive signal strength is used to determine the path loss by Station A. The difference between the path loss values is used to update the average differential number, which over a number of transmissions will average any fluctuations in path loss between transmission and response.

Having the differential number is also useful, in that on hearing a station probing or communicating to any other station, a path loss can be calculated using the correction factor and an estimation of the required transmit power to use can be made to reach the distant station with sufficient signal to noise ratio. The path loss delta or correction factor is only updated when stations are interacting with each other and this field will only be present in a transmission when a station is responding to another, and will not be present when another station is simply probing, when this field is left empty.

DATED THIS 1ST DAY OF AUGUST 1997

SPOOR AND FISHER
APPLICANT'S PATENT ATTORNEYS

976885

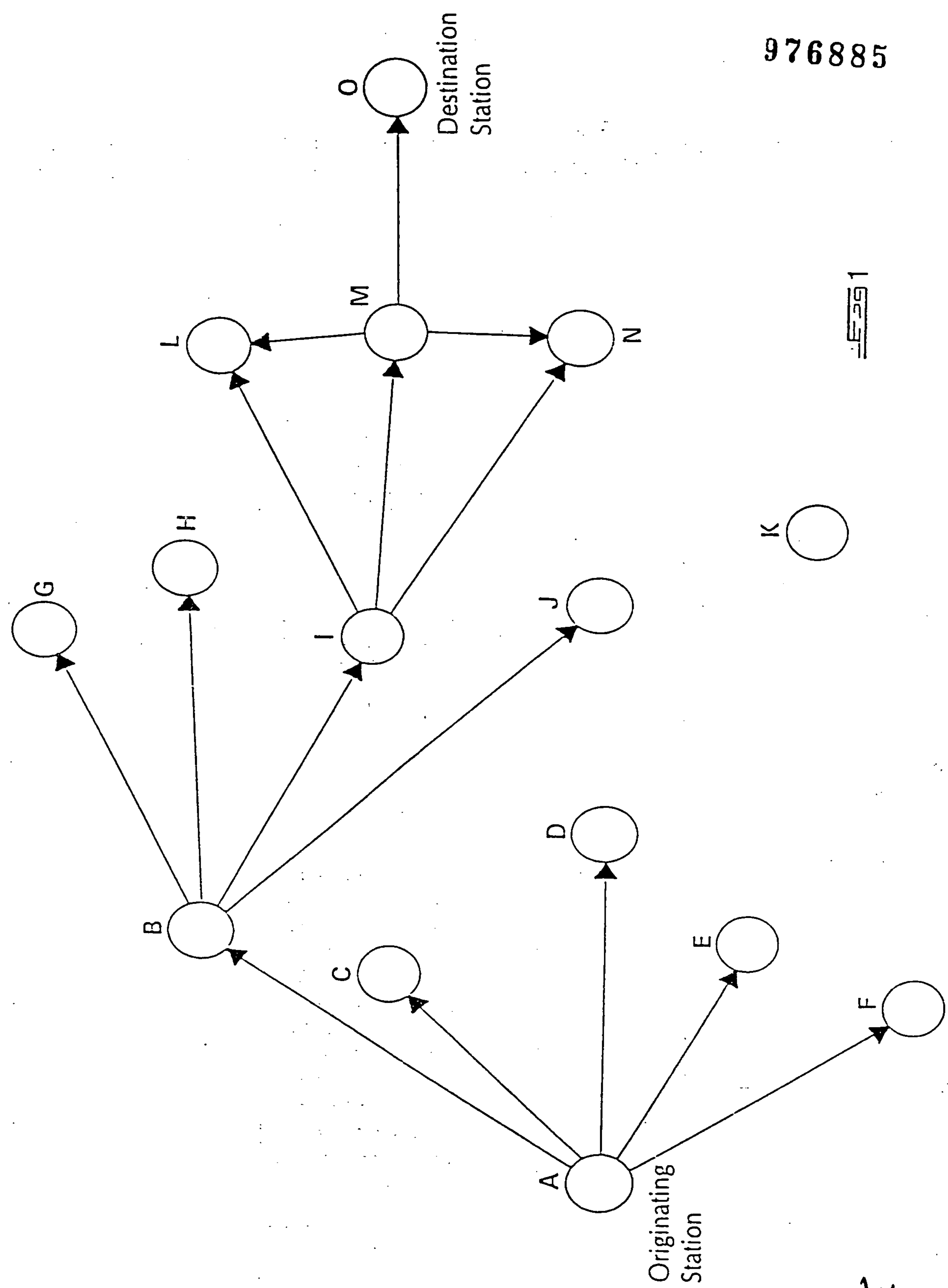

FIG 1

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FIG 2A

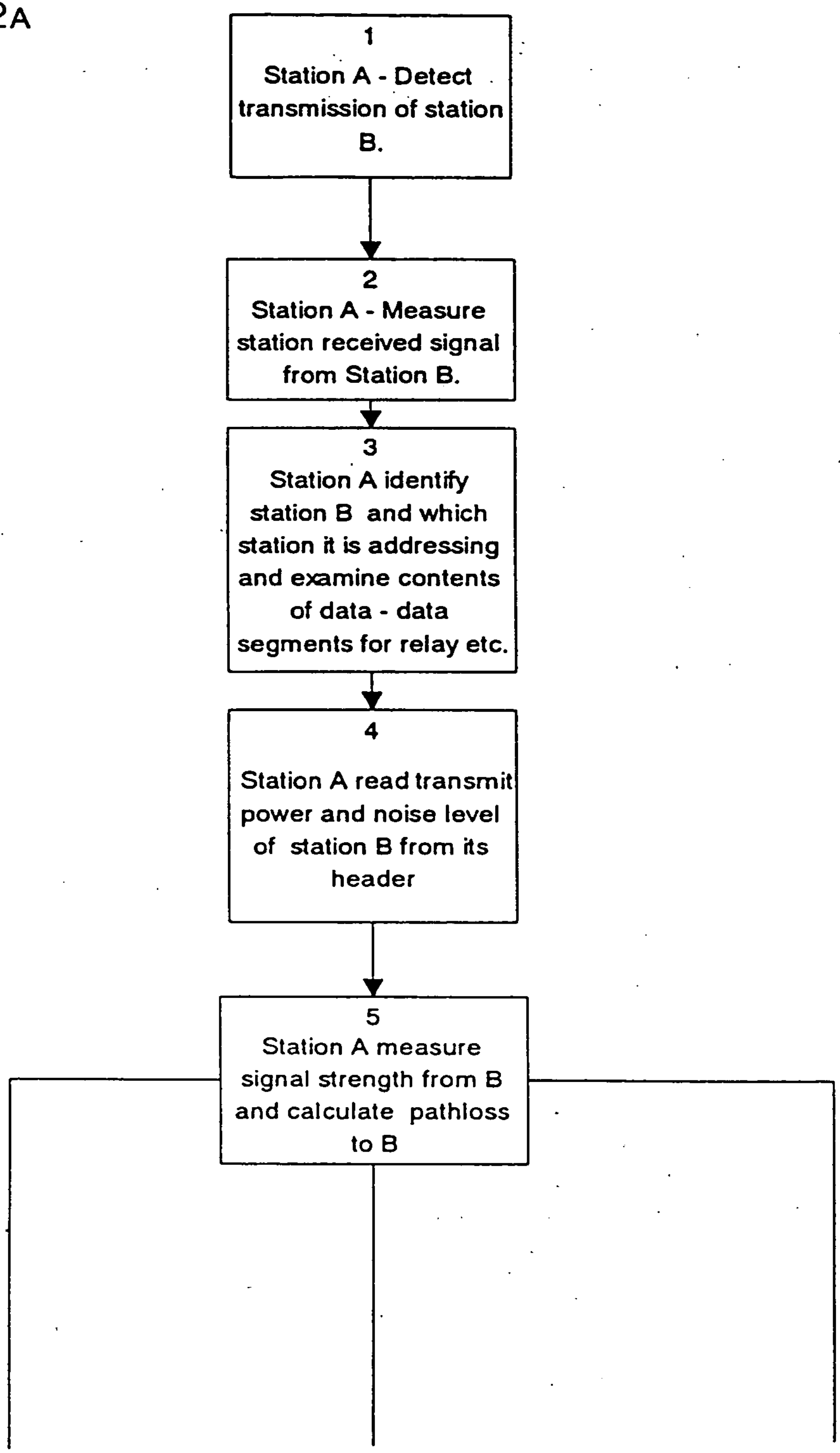

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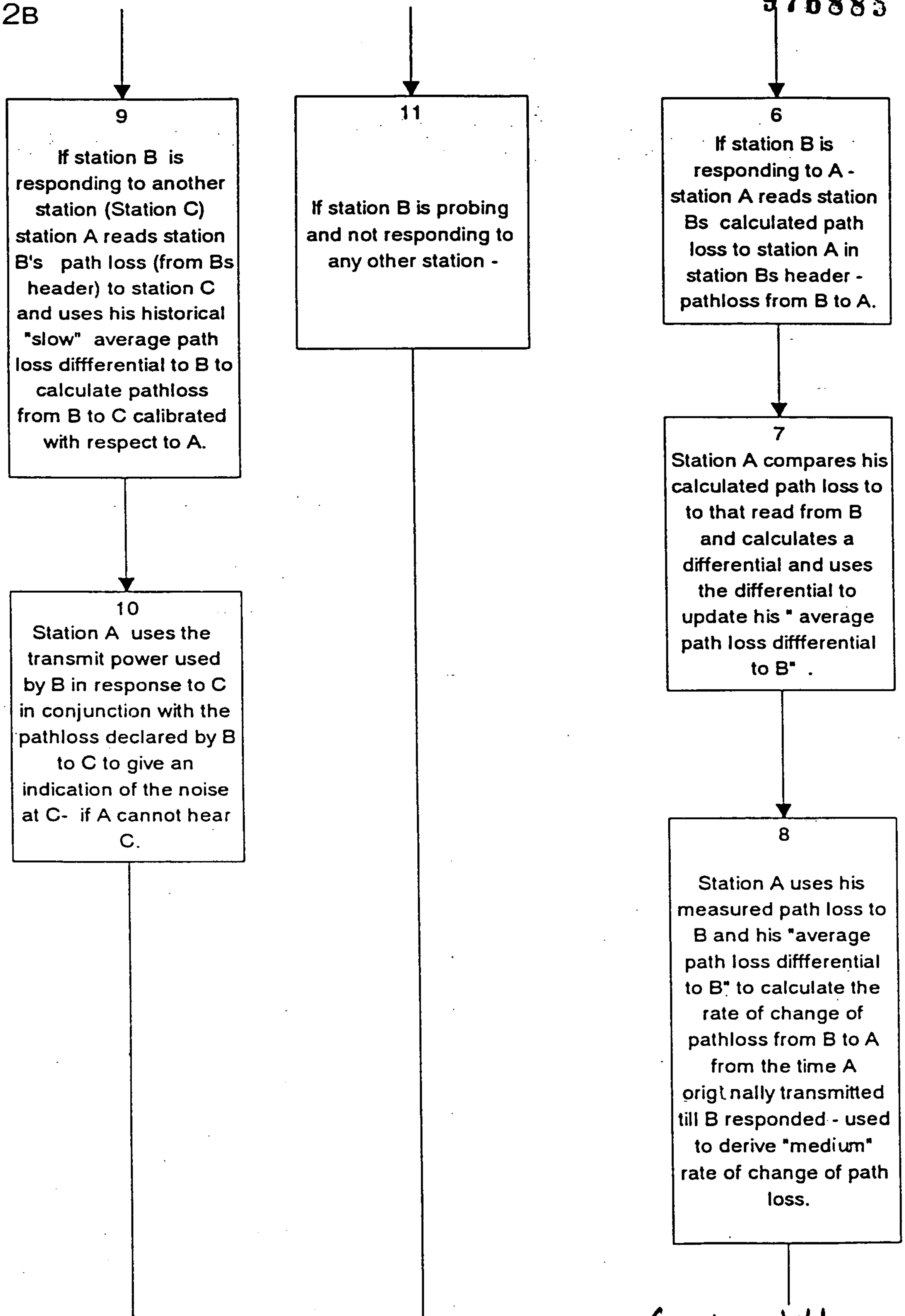
FIG 2B



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2C

12

Station A uses his measured path loss to B and the rate of change of this path loss during B's transmission to calculate pathloss from B to A and "fast" path loss variation from B to A - taking into account the correction factor -" average path loss diffferential to B"

13

Station A uses his calculated pathloss from B to A and updates his database and calculates a "slow" rate of change of pathloss based on past records - used to determine intermediate pathloss variation.

14

Station A uses the noise level declared by B to update his database and calculates a "slow" rate of change of noise based on past records - used to determine intermediate noise variation.

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FIG 2D

15
Station A uses calculated pathloss from B to A in conjunction with station B local noise (from Bs header) to calculate transmit power required to reach B - taking into account the rate of change of pathloss and noise from database both "fast" and "medium".

16
If the measured data indicates a "min imum" in path loss and/or a "min imum" in noise floor at B an "opportunity" is identified between A and B.

17
If A has data for B as a final destination or a relay - and the "opportunity" identified by A to B is better than any other "opportunity" to any other station at that moment - A decides to transmit to B.

FIG 2E

18
A choses datarate and packet duration based on the ammount of transmit power available at A and the required signal to noise ratio for different data rates and packet durations at B - taking into account the rate of change of pathloss from A to B and noise at B.

19
A examines its transmit data que destined for B as a final destination or relay and "fills" the packet with data segments - were packet size is determined by data rate and duration decided on for the opportunity.

20
A receives acknowledgement from B or monitors to hear B transmit data further,

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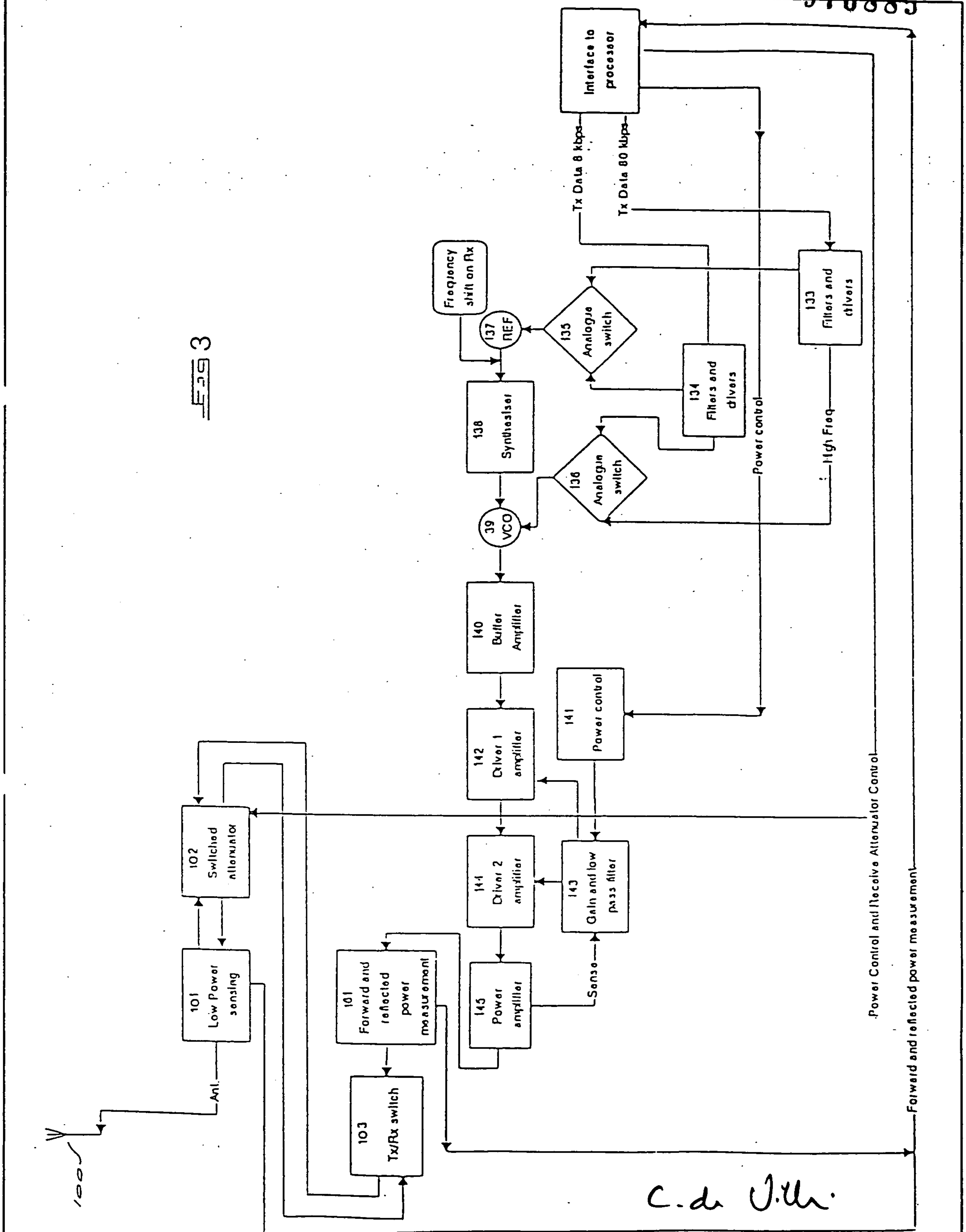

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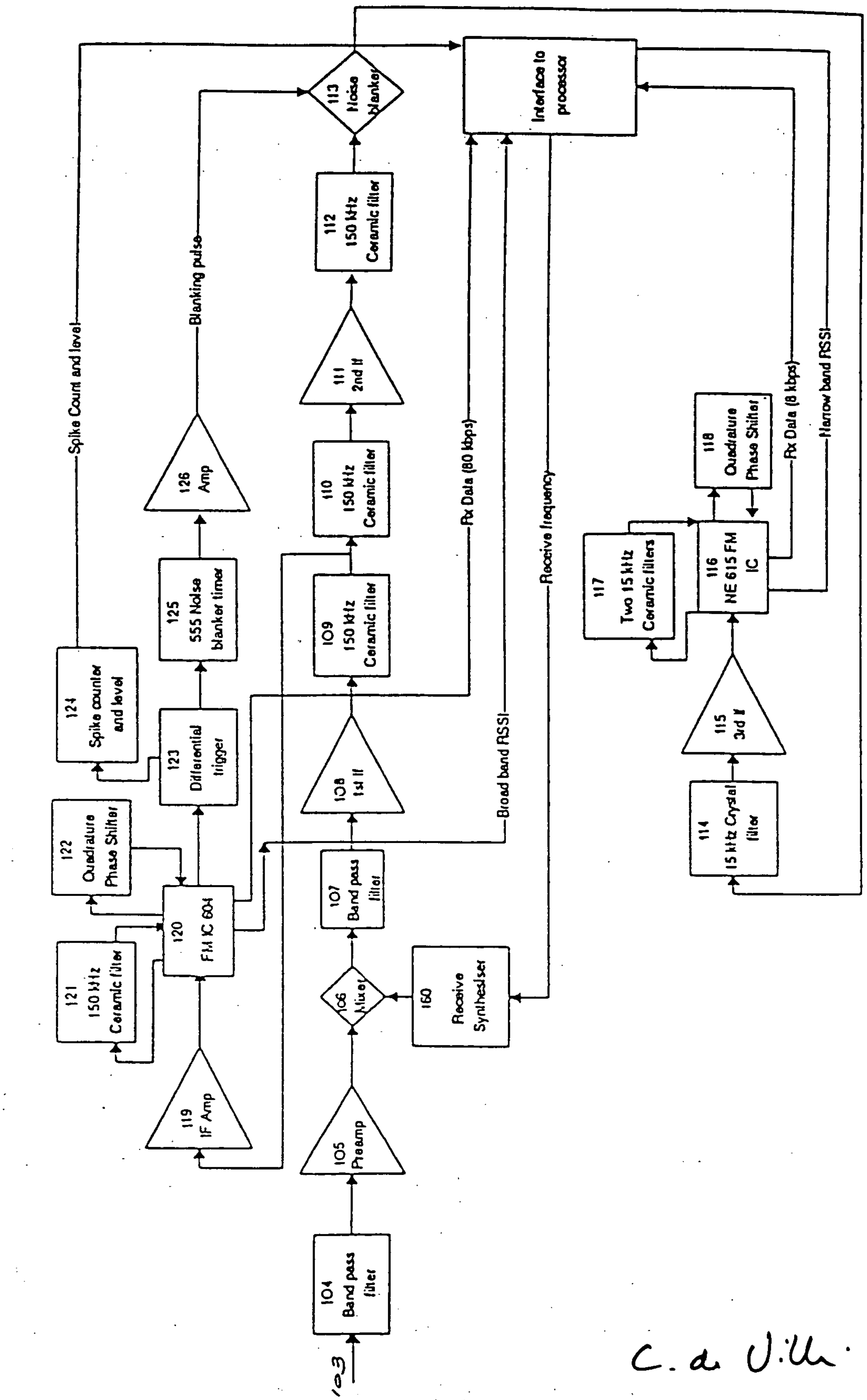

FIG 4

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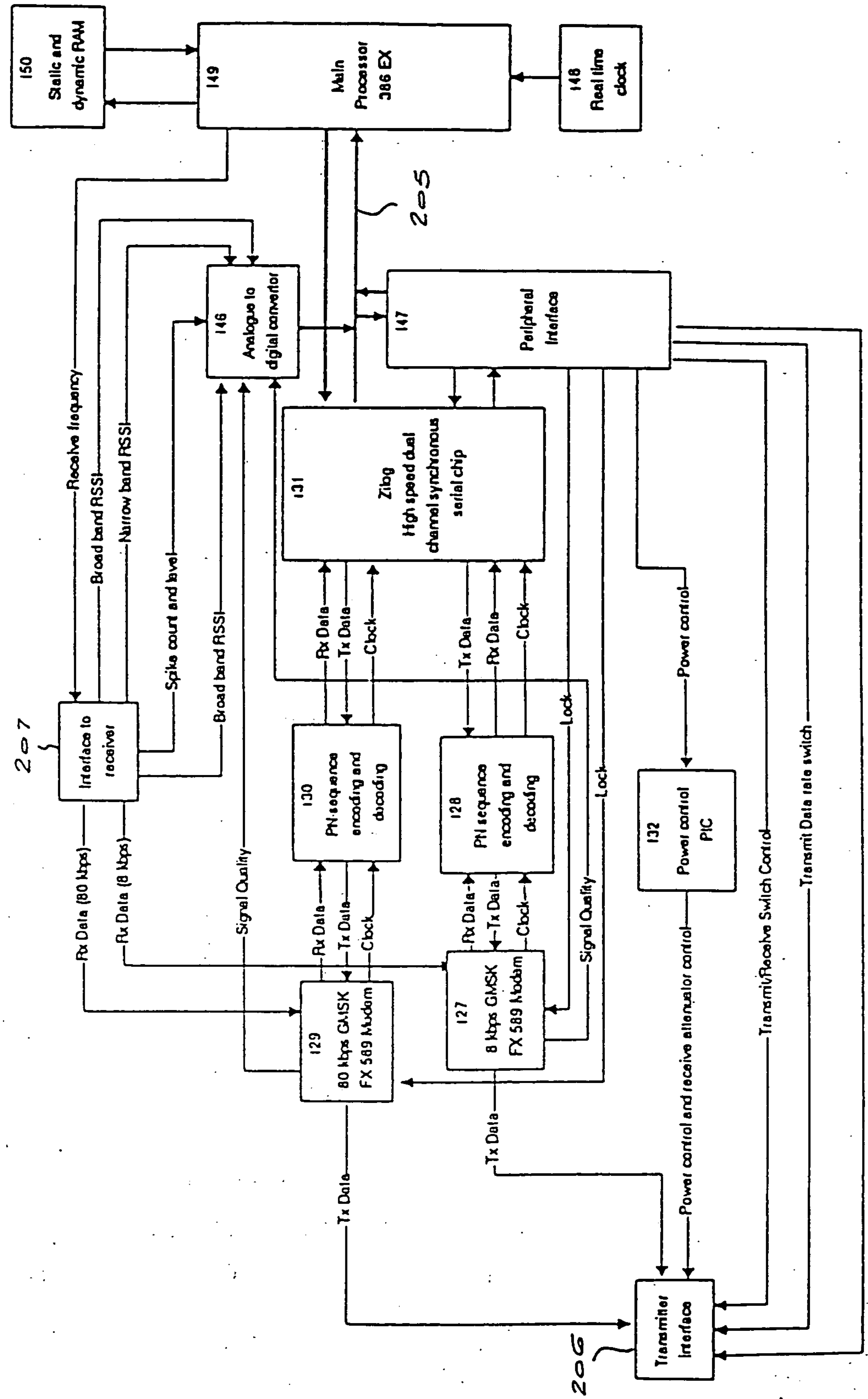

Fig 5

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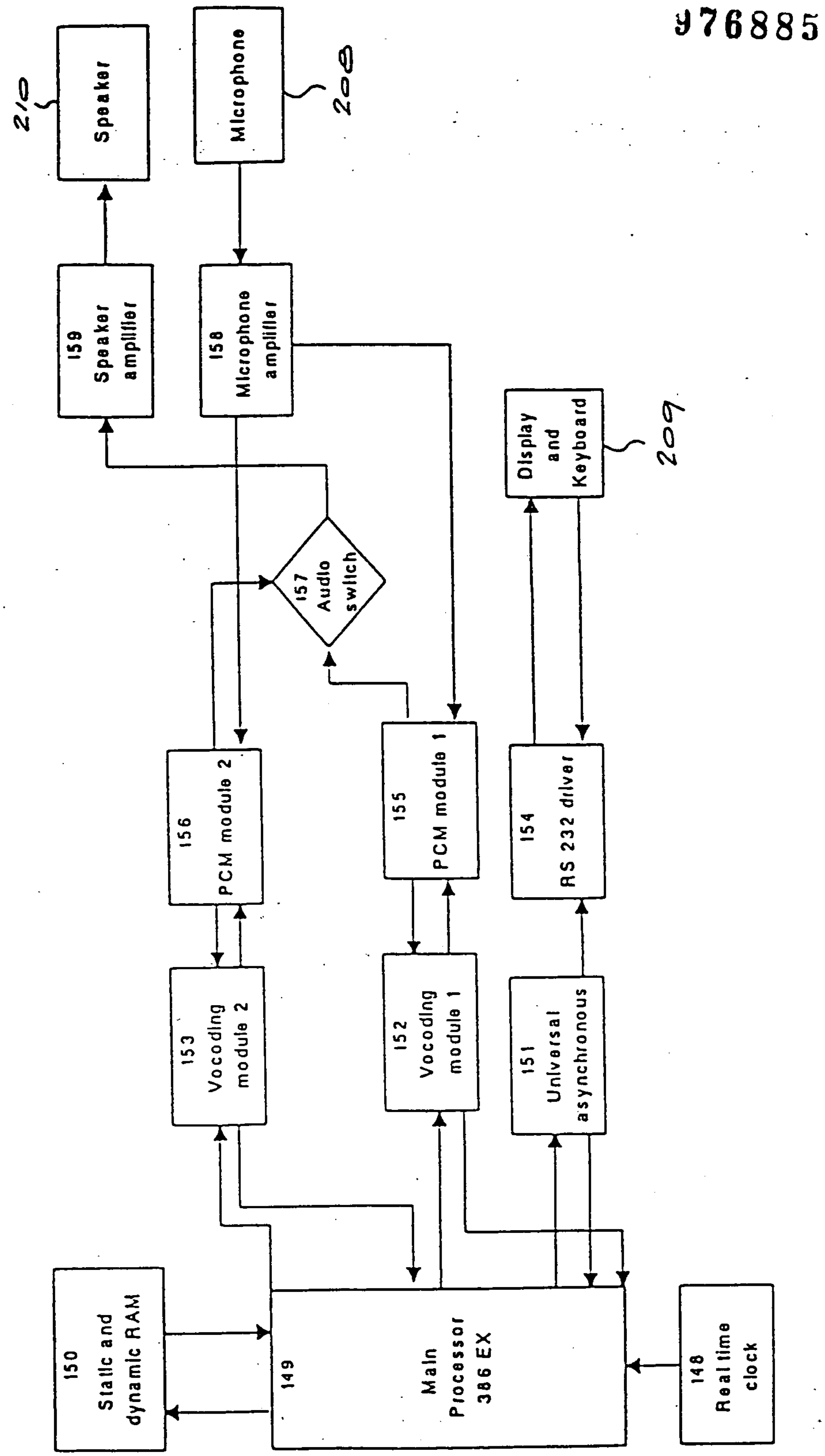

FIG 9

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